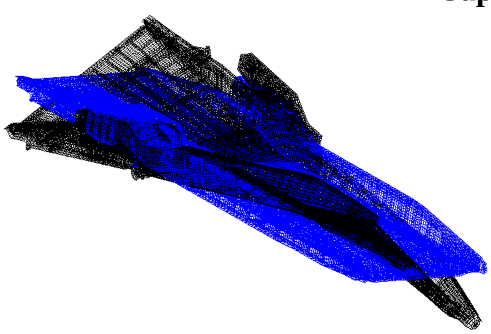
The Role of Model-Scale Testing of RORO Ramp Dynamics for Ramp Isolation Design

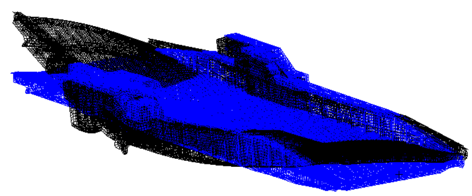
Joshua H. Gordis
Fotis A. Papoulias
Naval Postgraduate School
Dept. of Mechanical Engineering
Monterey CA 93943
(831) 656-2866
jgordis@nps.navy.mil

In Sea State 3 and above, the stern ramp of the Cape T ship is vulnerable to an overstress condition when off-loading vehicles. This overstress conditions arises due to the dynamic response of the ramp resulting from the relative motions between the ship (Cape T) at one end ("ship end") and the barge (RRDF) at the other end ("barge end"). From existing finite element models of several stern ramps (Cape T, Cape H, LMSR) it is clear that, for the excitation bandwidth imposed by the sea state, the lowest torsion mode and the lowest bending mode of the ramps play critical roles in the stress state of the ramp.

Cape T Stern Ramp



Mode 1: Torsion



Mode 2: Bending

Therefore, there exists a need to design motion-compensation devices ("isolation") which when placed between the end of the ramp and the barge, precludes the possibility of a ramp overstress condition.

To design such an isolation system, a computational analysis model is required, and is under development at the Naval Postgraduate School. The analysis model will allow candidate isolator concepts to be evaluated, and specific designs to be optimized. This model is a combined hydrodynamic/structural dynamic model ("combined analysis model"). At the current stage of development the model is in the frequency domain; an extended-phase time-domain simulation model will be developed following validation of the current model. Both the ship and the barge are represented as rigid bodies acted upon by the sea. An elastic (finite element) ramp model of the full-scale ramp is coupled to the ship and the isolation math model is coupled between the ramp and the barge. The wave inputs excite this system, and the response quantities of interest are the ramp displacements, velocities, accelerations, and stresses. Again, this combined analysis model will be used to predict the performance of candidate isolator concepts, and optimize the design of specific concepts.

In order to use this combined analysis model with confidence, the model must be validated by comparison with an experiment. Clearly, a full-scale test is not only prohibitively expensive, but does not allow repeated design analyses to be performed, such as would be required when optimizing a specific isolator concept.
Therefore, a laboratory-scale model will allow the combined analysis model to be validated.

The question therefore arises, which aspects or components of the combined analysis model of the full-scale hydro-structural dynamic system need to be validated by the experimental facility? Which aspects or components can be practically validated by the facility? It is important to keep in mind the following fundamental goal of this effort:

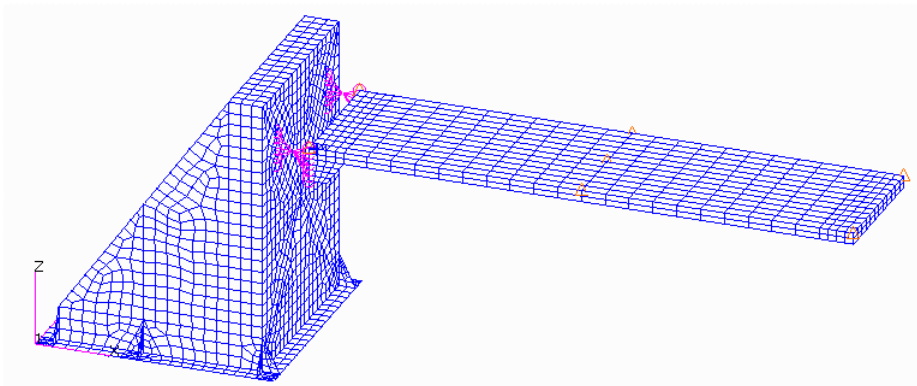
The combined analysis model is to be used to assess and/or optimize isolator concepts and designs. Therefore, what needs to be validated is the mathematical representation of the isolators used in the combined analysis model. The assumption implicit in this statement is that the validation of a mathematical isolator model can be done in an experimental facility that *approximately* represents the full-scale environment. As the isolators function as point-to-point impedances, and if the excitation bandwidth and loading of the actual environment are approximately and conservatively reproduced in the experimental facility, the assumption stated is indeed valid.

In order to answer the above questions, we will consider each major component of the entire dynamic system in turn.

(1) Multi-vessel hydrodynamics model: The experimental facility under development at NPS is a “dry” facility and hence does not attempt to provide validation of vessel hydrodynamic response. The hydrodynamic responses calculated based on data provided by well known and documented hydrodynamic prediction codes (WAMIT) can be validated by measured data taken off the coast of San Diego during the “Turbo Patriot 2000” JLOTS exercises. This data is expected by NPS.

(2) Ramp structural model: The finite element models of the full-scale ramps (e.g. Cape T) cannot be validated, i.e. the predictions of natural frequencies and mode shapes cannot be compared with measured data as no modal test has been performed on these ramps. The lack of a validated ramp model would cause difficulty in establishing a validated isolator model, because the dynamics of the ramp and isolator would “intermingle” and hence discrepancies between measured and predicted results could not be attributed to a unique source, i.e. either the isolator model or the ramp model.

Herein lies the critical importance of the scale-ramp in the experiment. The scale-ramp can be tested, and its natural frequencies and mode shapes measured. A finite element model of the scale ramp (which has already been prepared) can be validated using the measured data from the scale model. Therefore, the experimental facility will use a validated ramp finite element model and well-known and established hydrodynamics codes. The only component, which remains to be validated, is the isolator model, and that is the purpose of the experiment. In other words, when measured data taken from the experimental facility is compared with the corresponding data from the combined analysis model, and differences between the data sets can be attributed solely to the isolator math model. The isolator math model can therefore be adjusted so that it accurately represents the physics of the isolator. Once this is done, the isolator math model can be used in the combined analysis model with confidence to assess the performance of the isolator, and to optimize the design of the isolator.



Finite element model of scale-ramp test facility: Ramp is 2 ft wide by 8 ft long, Aluminum plate. Scale ramp weight is approximately 250 lb (including weights representing tank mass, etc.) Ramp support structure is a steel weldment weighing approximately 500 lb.